AN ARTIFICIAL INTELLIGENCE AND DEVICE FOR DIAGNOSIS, SCREENING, PREVENTION AND TREATMENT OF MATERNO-FETAL CONDITIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon U.S. Provisional Application serial no. 60/526,313, entitled AN ARTIFICIAL INTELLIGENCE AND DEVICE FOR DIAGNOSIS, SCREENING, PREVENTION AND TREATMENT OF MATERNO-FETAL CONDITIONS, the entirety of which is incorporated herein.

BACKGROUND OF THE INVENTION

For a newborn, facing the outside world involves adaptations that start with the first milliliter of oxygen ventilating the lungs and continue throughout life. These adaptations involve all organs, systems, and an intricate network of independent and interdependent functions. A normal structural, functional and aesthetic status at birth is essential in order to enjoy what life offers and to deal with adverse situations adequately. An early and optimal detection of problems/complications during pregnancy and the best practice when handling of all risks during intrauterine life is beneficial for the patient, her family, the healthcare system, and society as a whole.

Pregnancy complication may be caused by a long list of thousands of conditions belonging to several classes:

a) existing risk of abnormal genetic inheritance at chromosomal level or at level of molecular genetics or at biochemical or metabolical level

Eg. Down's Syndrome, Turner Syndrome, and other thousands of conditions.

b) existing risk of fetal structural anomalies without detectable abnormal genetic pattern

Eg. Spina Bifida and other thousands of conditions.

c) Idiopatic fetal malformations and diseases

Eg. Hydrops Fetalis, Fetal Growth Retardation, Fetal Macrosomia

d) Fetal Diseases and pregnancy complications resulting form exposure to maternal diseases or to abnormal or untimely changes of the maternal/uterine physiology

Eg. Maternal diabetes causing fetal structural anomalies or fetal macrosomia

e) Fetal disease resulting from exposure to teratogenetic or other types of damaging agents

f) Sporadic Genetic Mutations

g) Other Problems

What is needed is an artificial intelligence software allowing for plotting, planning and handling all fetal, maternal and external pre-existent data and occurring date during pregnancy will improve the screening, detection, prevention and treatment of every case, thus improving the chance of the delivery of a neonate in the best condition to face life.

SUMMARY OF THE INVENTION

The present invention relates to a time-oriented artificial intelligence system to handle any diagnostic screening or treatment of complications or risks throughout pregnancy.

A user can insert a problem or query relating to clinical case management during a pregnancy and receive case oriented output guiding the management of the case via at least one algorithm.

The invention allows detection of phenotype following an abnormal genotype.

The present invention provides an expert system for optimizing health during pregnancy comprising at least one database of pregnancy related health complications. Such a database may in fact include any number of databases, and such databases can be connected in any fashion, such as by hyperlinking. The system also comprises data representing time oriented information about any of said health complications The health complications may be classified into said data menus. The

expert system can include at least one input for inputting diagnostic and/or screening data. The system may also include at least one indicator for reporting a decision as a function of the inputted diagnostic and screening data.

The system may include data menus. The data menus comprise categorically defined pregnancy related health conditions, said data menus being organized as a function of the pregnancy time period. These categorically defined pregnancy conditions can be classified in any number of ways.

An intelligent agent comprising at least one algorithmic rule adapted to apply to data inputted into the intelligent agent can be included. The rule can be designed to produce at least one decision about a pregnancy case. A decision may include scheduling at least one action to be taken with respect to the complication or detecting said complication. Actions that can be taken with respect to the complication include screening for the complication or treating the complication .

The intelligent agent may be configured to accept said inputted diagnostic and/or screening data and indicate the probability of the presence or absence of a pregnancy related health complication. It can do this using any number of rules. The application of said rules to inputted data, including diagnostic and screening data and health complication data is factored to report at least one decision indicating the likelihood of at least one potential health related pregnancy complication.

The intelligent agent may also include at least one incidence rule indicating the incidence of at least one pregnancy complication after birth as well as at least one incidence rule indicating the incidence of at least one pregnancy complication as a function of time during pregnancy. The application rule can be used to weigh the likelihood of a given syndrome. The agent may also include at least one classification rule directed toward classifying the at least one complication.

The intelligent agent may also include at least one association rule, said rule associating at least one decision derived from any of the above-described rules or the intelligent agent. The application of each of any of the rules included in the intelligent agent to inputted data is factored to report at least one decision indicating the likelihood of at least one potential health related pregnancy complication. Decisions or other data generated by applying the rule to diagnostic and screening data may be communicated back into the database such that it adds to the knowledge base accessible to the rules engine.

The expert system comprises a computer executed program for categorically classifying and accessing the inputted diagnostic and/or screening data and the database data. The system may also be configured to issue advisory report on future actions to be taken. Similarly, it could be configured to generate an alert based on inputted data.

DETAILED DESCRIPTION OF THE INVENTION

The system and method of present invention provides an expert system for optimizing health during pregnancy or after birth comprising at least one database of pregnancy related health data, including pregnancy complications. Complications, as used herein, refers to any health related issue directly or indirectly related to a procedure (or risk of the procedure), treatment (including side effect or toxicity), illness, condition, abnormality or anomaly, or syndrome. The present invention manages information about complications related to pregnancy, and so complications comprise any issue that presents a concern with respect to the optimal health of either a fetus, a mother, or both. Thus, complications could comprise a syndrome, an anomalous event, nutrition or malnutrition, environmental factors, mutations at gene level, family history (e.g.: a history of retardation in the family), or even maintenance issues. Such a database may in fact include any number of databases, and such databases can be connected in any fashion. The system also comprises data representing time oriented information about any of said health complications The expert system can include at

least one input for inputting diagnostic and screening data. The system may also include at least one indicator for reporting a decision as a function of the inputted diagnostic and screening data.

FIG. 1 shows an overall non-limiting exemplary schematic layout of the present invention. Data source **110** containing diagnostic and/or screening data from a patient is fed into an inference engine or intelligent agent **120** which outputs decisions **130a, 130b, 130c**. The decisions **130a, 130b, 130c** may be derived from data bases **140** using dedicated algorithms. The inference engine **120** is operatively connected to at least one knowledge database **140** comprising pregnancy related time-oriented health data, neonatal related data and gene mapping. A map of the chromosomes can be linked to in the Human Genome Database (e.g:: the map of chromosome 16, http://www.gdb.org/gdbreports/Chr.16.omim.html).

The present invention may make use of, for example, a database of information related to both normal and abnormal fetal and extrauterine development over given time period. Database information may also be information enriched from the inference engine **120** itself into the database.

The knowledge data bases include time oriented menus including, *inter alia*, 1) genetics and genomic data base; 2) teratogen exposure before and during pregnancy; 3) maternal diseases having an impact on the fetus; and 4) events and markers related to prematurity.

The intelligent agent comprises temporal reasoning logic. Exemplary temporal logic and information about it can be found in each of the following references, the entirety of which are incorporated herein:

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The inference engine / intelligent agent can make decisions using cumulative weighted considerations of the following exemplary variables:

- the incidence of a syndrome at birth;

- the incidence or the syndrome during gestation by week of the gestation period;
- the incidence of signs or markers inside each syndrome at birth;
- the incidence of each sign or marker inside each syndrome by week of the gestation period;
- the incidence of the associations of signs or markers at birth;
- the incidence of the associations of sign or markers during gestation by week of the gestation period;
- classification of each sign or marker as main, secondary, or rare with respect to a syndrome at birth;
- classification of each sign or marker as main, secondary, or rare with respect to a syndrome during gestation by week of the gestation period; and
- classification of each sign or marker by its natural history type (i.e. Types I-IV described herein.)

It will be recognized that the weighted value of each of the above elements and variables, as well as other variables, will vary according to case and situation, as well as accounting for other factors such as ethnicity.

According to their natural history, fetal anomalies can be classified in four types (Types I to IV): Type I -Early onset at constant gestational age; Type I -Transient condition; Type III -Variable onset or potentially unstable anomalies; and Type IV -Late onset anomalies. Examples of anomalies for Type I – Early onset at constant gestational age are: Anencephaly, bifida, Conjoined twins, Holoprosencephaly, Cyclops deformity, Osteogenesis imperfecta type II, Dextrocardia, Double collecting renal system, Anophthalmia, or Facial cleft. Examples of anomalies for Type II – Transient Conditions are: Increased NT , Pleural effusion, Pericardial effusion, Choroid plexus cysts, Hydronephrosis, Mesenteric cyst, Echogenic bowel, Oligohydramnios, Placental hypertrophy , or

Cardiac Arrhythmia. Examples of anomalies for Type III - Anomalies with variable onset or potentially unstable anomalies are: Diaphragmatic hernia, Hydrocephalus, Clubfoot, Dandy-Walker, Malformation, Coarctation of aorta, Ovarian cyst, AV heart block, Exomphalos, Megacystis, or Encephalocele. Examples of anomalies for Type IV- late onset anomalies are: Agenesis of the corpus callosum, Lissencephaly, Porencephaly, Microcephaly, Intracranial arachnoid cysts, Scaphocephaly, Congenital mesoblastic nephroma, Pyloric atresia, or Osteogenesis imperfecta type IV. Additional information about natural history of fetal anomalies may be found in the following reference which is incorporated in its entirety herein: Rottem, Shraga: IRONFAN – Sonographic window into the natural history of fetal anomalies, Ultrasound Obstet. Gynecol. 5 (1995) 361-363.

A series of non-limiting exemplary embodiments of the system and method of the invention is described in terms of display views (e.g. screen shots) in **FIG. 2** to **FIG. 4B**. **FIG. 2** shows a first screen exemplifying the relation between the time-oriented inference engine and the time-oriented knowledge bases. The time bar **10** allows coordinate access to the knowledge bases based on gestation time period. Knowledge bases **D1 to D12** categorize pregnancy complications into various classes. **D1 to D12** include data relating to maternal disease, fetal system development, genetic risk, risk of fetal anomaly (e.g. polydactyly) drug use before or during pregnancy or any other categorical classifications useful in managing pregnancy care. Data menus **D1-D12** include data useful in diagnosing, screening, treating, and managing a pregnancy case.

The bar **10** can be designed to have normal fetal organs and organ functions or values on the left-hand side and abnormal fetal development and dysfunctions on the right-hand side, values resulting through tests such as ultrasound and other tests. A tab **12** can be designed to mark a point on a sliding scale to indicate a precise point or stage of the pregnancy, for example 11 weeks and 1 day. Each data menu **D1 to D12** is designed with a timing bar including a tab scale **11**. The timing

scale **11** can be operatively coordinated to the time oriented bar **10** such that each data menu reflects the time of pregnancy and shows conditions related to that time of pregnancy.

FIG. 2A illustrates a screen that is presented to a user when the user chooses access data menu for example **D8**. The user could choose a menu for example **D8** wherein health related pregnancy conditions are genetic conditions. A scale **21** is presented to indicate the time period of the pregnancy. A second data-menu **20** may show a list of options with queries which can be made relating to a genetic problem.

The options for the queries can be : a list of genetic disease; and subcategories thereof; by a marker from sonographic or biochemical investigation showing a risk or other risks.

A selection from menu **20** would open another menu **25** which provides a list of syndromes which can be detected at this gestation age. Once a syndrome is selected, the hereinabove described algorithm generates of screen as shown in **FIG. 2B** For example, if a genetic list were selected, the list would show chromosomal, non-chromosomal, metabolic, mendelian, and mental deficiency as the relevant complications to be screened for.

FIG. 4B is an illustration of a screen showing the anomalies and association of anomalies to look for using the algorithm based planning. The planning may change depending upon the presence or absence of an anomaly or anomalies in later scans.

FIG. 4C shows a screen in which the SonoMarker list has been selected. A query can arise form the selection of a SonoMarker from the list such as anomaly 101. In such a case the algorithm will provide the most common syndrome to look for at this time of pregnancy.

However, out of the long list of signs for a syndromes, the algorithm will provide the weighted probability of looking for the smallest number of markers to detect or exclude the syndrome. An example of such a list is shown in **FIGS. 2C and 2D.**

One of the urges of finding information is to look to data bases from neonatal outcomes from cases with polydactyly. This in impractical since it would involve a study of over 200 different syndromes. The algorithm from this invention directs the practitioner to the most common syndrome in the fetus with polydactyly at a particular gestational age. However, instead of looking at over 40 possible associate signs, the algorithm shown in **FIGS. 2C and 2D** directs the user to two signs (increased NT and Occipital Encephalocele) followed by polycystic kidneys at a later stage. According to a new evaluation of the fetus, Meckel Gruber syndrome is confirmed or excluded, the next further indicated syndrome by their probabilities and associated signs in shown.

In addition to by syndrome or by marker algorithms, the invention also includes the ability to flag a list of the least number of the markers to detect the maximum number of syndromes/diseases at a given gestational age. In addition to above-describes software, this can be achieved by a jog dial with programmable button.

Two additional queries which can be generated using the algorithm of this invention are shown in **FIG. 3A** and **FIG. 4A.** **FIG. 4A** shows the query relating to possible impact from maternal disease on fetal health at a given time in the gestation.

FIG. 3A relates to the query to the inference engine and algorithm on the possible impact on the fetus from maternal exposure to a teratogen.

FIG. 3A displays one of possible embodiments of the query mode on the possible impact of maternal exposure to any teratogen at any time in gestation. The classes and subclasses are shown in menu **40**. The query would include selection of a drug, time of exposure in weeks and days and dose (not shown in screen). The inference engine and algorithm will declare as non relevant or relevant to fetal health. In case of non-relevance the screen will the reassuring reasons for non-relevance. If the answer is relevant as dictated by the inference engine and algorithm the output will indicate the time for detection of possible problems in the fetus as shown in **FIG. 3B.**

FIG. 3A shows another example of the screen that could be accessed from the first data menus **D1, D2, D3** from the access screen of **FIG. 2** For example, a user could select a menu **D3** of conditions related to teratogens. At **FIG. 4A** is shown list or menu **40** of pregnancy complications, here being teratogens, exposure to a drug for example. A display **42** shows the time of exposure to the teratogen, for example a drug taken during week 5, day 3, and dose of the drug (not shown here). A result could then report information about the drug exposure and the time of pregnancy. For example, a report box **44** could indicate whether the exposure to the teratogen is relevant to fetal development or is irrelevant. If irrelevant, the system can be configured to give a reason in second reporting box **46**. A time oriented rule indicates the relationship between the diagnostic and screening information and the time of pregnancy. As an additional feature, the expert system could adapted to prompt a pregnant patient, during a sonogram for instance, and ask her if she has taken a given drug. If so, the intelligent agent process that information as described with respect to a teratogen.

If the exposure is relevant, the user can then bring up a page shown at **3B** similar to that later described in **FIG. 4B**, with the time period being directed toward the time of pregnancy of the

present example. The complications, results, actions, anomalies etc., would be related to the relevant effect of the teratogen, although it need not be limited to this.

FIG. 4A displays the possible impact on the fetus of a maternal disease during pregnancy. Menu **30** shows a list of possible maternal diseases. According to the week of gestation, the tests relating to the disease such as antibody levels and other tests, the inference engine and the algorithm will provide an output indicating whether the values of the tests of maternal disease will be too high or too low considering to what would be normal levels for the fetus. According to high or low level, a chart , shown at **FIG. 4B** will indicate the follow up with the fetus in the same manner as with the teratogen.

FIG. 4A shows another example of a screen that could be accessed from the first data menus **D1 to D12** from the access screen of **FIG. 2.** For example, a user could select a menu **D2** of conditions related to maternal diseases, for example anemia, diabetes, liver disease, renal failure, etc.). At **FIG. 4A** a display **42** for the time of pregnancy may be presented to user. For example the screen could show that a pregnancy case is on week 12, day 5. Also presented can be a list or menu **40** of pregnancy complications, each of which are associated with that time period and the selected condition of first menu **D1** of **FIG. 2.** For example, the list could comprise diseases and subcategories of these diseases. The display could also present a user with a diagnostic and screening information, such as the level of antibodies present in the blood (e.g. .0.56). This may be data inputted from any test. The display could also show additional diagnostic and screening data, such as when the disease first began (not shown). A result could then report information about the diagnostic and screening information and the time of pregnancy. For example, the screen could indicate whether, given the disease, the amount of antibodies is low or high with respect to the effect on the fetus the 12th week and 5th day of pregnancy . A time oriented rule could be designed

to indicate the relationship between the diagnostic and screening information and the time of pregnancy.

The user can then bring up a page similar to that already described in **FIG. 3B**, with the time period being directed toward the time of pregnancy of the present example. The complications, results, actions, anomalies etc., would be related to the maternal diseases as that was the initial menu selected, although it need not be limited to this.

ADDITIONAL FEATURES

A feature that may be included in the expert system is one where the system may be configured to issue advisory report on future actions to be taken. It could also be configured to issue an alert based on the need to take an action where such an action should have been taken earlier but was not. Similarly, it could be configured to generate an alert in the event that there was a misdiagnosis in the past. The expert system could issue such an alert when, for example, an earlier diagnosis without the benefit of the present invention diagnosed a condition or syndrome that the system knows cannot co-exist with an anomaly that was previously diagnosed as well. The system could then be adapted to indicate a new course of treatment or other actions based on the misdiagnosis.

The expert system may also comprise an operating system comprising an input for data relating to mother's condition and the fetus's condition. The data about the fetus may include the gestational age of the fetus. The gestational age can be is established by any diagnostic and screening method, including for example an ultrasonographic method, said ultrasonographic method including fetal biometer. A scaled plotting tool may also be included to plot inputted test result data, wherein the inference engine can output a decision as a function of the plotted data.

The expert system of the present invention may embedded into any diagnostic and screening device. It may also be accessible by the web to allow remote use by any user.

It should be understood that the above description is only representative of illustrative embodiments. For the convenience of the reader, the above description has focused on a limited number of representative samples of all possible embodiments, samples that teach the principles of the invention. The description has not attempted to exhaustively enumerate all possible variations or even combinations of those variations described. That alternate embodiments may not have been presented for a specific portion of the invention, or that further undescribed alternate embodiments may be available for a portion, is not to be considered a disclaimer of those alternate embodiments. One of ordinary skill will appreciate that many of those undescribed embodiments, involve differences in technology rather than differences in the application of the principles of the invention. It will be recognized that, based upon the description herein, most of the principles of the invention will be transferable to other specific technology for implementation purposes. This is particularly the case when the technology differences involve different specific hardware and/or software. Accordingly, the invention is not intended to be limited to less than the scope set forth in the following claims and equivalents.